Parallel Evolution in the Northern Scorpion *Paruroctonus boreus*

Zachary J. Valois, *Utah State University / Utah Museum of Natural History* | Dr. Zachariah Gompert, *Utah State University* | Dr. Lorenzo Prendini *American Museum of Natural History*

I. Introduction

Parallel evolution occurs when the same trait evolves independently in multiple, closely related populations (**1**). This study is part of a larger project to investigate a putative case of parallel evolution in the Northern scorpion, *Paruroctonus boreus*. Northern scorpions generally exhibit a darkly mottled appearance and are found in consolidated sage steppe nearly throughout the entire Great Basin desert, but pale color forms are often associated with dune systems (**2**, see Fig. 1-6) as are elongated tarsal setae in other taxa (**3**).The overall goal of this study is to test the hypothesis that natural selection has driven parallel evolution of pale color across dune populations.

Objectives:

1: Analyze morphological patterns of facultative dune populations in *P. boreus* to test for associated morphological variation.

2: Analyze patterns of genetic variation within and among dune and non-dune populations of *P. boreus* to determine whether pale dune populations have descended from one or multiple non-dune populations.

3: Determine whether specific genomic regions are associated with the possible repeated evolution of a pale ecotype.

Figure 1 (left) shows a pale individual found in a dune system. **Figure 2 (right)** shows a typical colored individual found on consolidated soils.

II. Methods

Specimens:

For this pilot study, we examined collection holdings of the Utah Museum of Natural History.

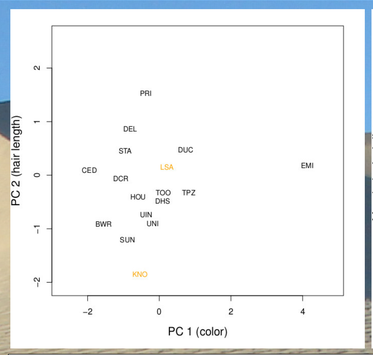
Morphological characters analyzed:

- Tarsal macrosetae number
- Tarsal macrosetae mean length
- Grayscale value of two dorsal body segments

Method of mensuration & analyses:

- Lieca EZD HD microscope – to capture digital images
- ImageJ 1.47v – for all measurements, taken from scaled digital images
- R: version 3.0.2 – for Principle Component Analysis

Figure 3 (above left) and **figure 4 (below left)** show phenotypes often associated with dune systems. **Figure 5 (above right)** and **figure 6 (below right)** show phenotypes often associated with higher elevation, rocky habitats.



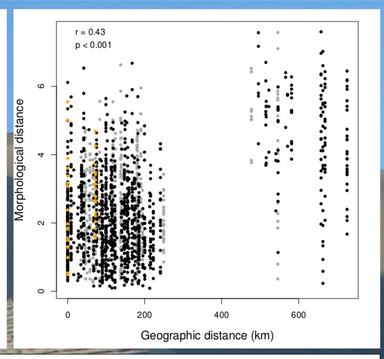


Figure 7 (left) shows the resulting PCA plot for color and mean tarsal seta length. Abbreviations in yellow represent dune occurring populations, those in black are non-dune populations. **Figure 8 (right)** shows morphological (Euclidean) distance plotted against geographical distance, showing that the further apart two populations are geographically, the more different they are morphologically. Yellow marks represent dune compared to dune individuals, gray represent dune by non-dune individuals, and black represents non-dune by non-dune individuals.

III. Results

- At least one dune population exhibits an extreme phenotype (Fig. 7) – longer tarsal setae.
- The further two populations are from each other geographically, the more different they are morphologically (Fig. 8).
- Initial results failed to separate dune populations on the basis of color. We attribute this, at least in part, to low sample sizes (n=62) and condition of preserved specimens (e.g. possibility of faded color or broken tarsal setae).

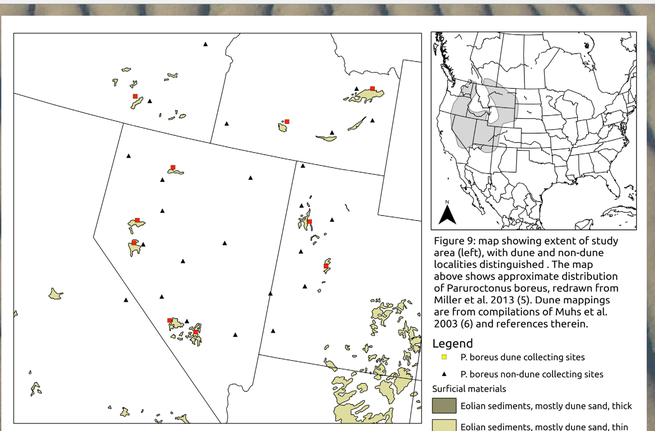


Figure 9: map showing extent of study area (left), with dune and non-dune localities distinguished . The map above shows approximate distribution of Paruroctonus boreus, redrawn from Miller et al. 2013 (5). Dune mappings are from compilations of Muhs et al. 2003 (6) and references therein.

IV. Conclusions

This work represents a pilot study that aims to better understand the pattern and process of evolution of color in scorpions. We chose the facultative psammophile, *P. boreus*, as this species is associated with a history of taxonomic and phylogenetic confusion, largely as a result of variable color forms found throughout it's range(**2, 4**). We plan to continue this study and will next begin collecting scorpions for further morphological and molecular analyses (see Fig. 9 for map of planned survey sites).

With this information, we may better understand phenotypic diversity within this species, candidate loci associated with color, and the propensity of repeated adaptation to dune systems. These results could also explain the persistence of cryptic genetic lineages of *P. boreus* (as inferred by Miller et al. 2013) and would highlight the contribution of selection to biological diversification.

If our hypothesis is correct, a population level phylogeny should reflect a pattern more or less similar to the hypothetical tree depicted in figure 11.

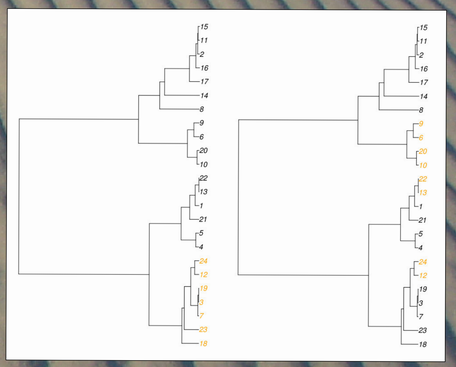


Figure 10 (left) shows a hypothetical phylogenetic tree that would be expected If all dune populations share a common ancestor. **Figure 11 (right)** shows the expected tree if dune populations have multiple ancestors.

Zachary J. Valois
Utah State University / Dept. of Biology
Utah Museum of Natural History / Invertebrate Collections
Z_Valois@yahoo.com - www.zachvalois.weebly.com

Work Cited:
1 – Schluter, D. E. et al. 2004. Parallel evolution and inheritance of quantitative traits. *American Naturalist*, 163: 809-822.
2 – Haradon, R. M. 1985. New groups and species belonging to the nominate subgenus *Paruroctonus*. *J. Arachnology*, 13 (1): 19-42.
3 – Fet, V. et al. 1998. Life in sandy deserts: the scorpion model. J. Arid Environments, 39: 609-622.
4 – Sissom, W. D. and O. F. Franke. 1981. Scorpions of the genus *Paruroctonus* from New Mexico and Texas. *J. Arachnology*, 9 (1): 93-108.
5 – Miller, A.L. et al. 2013. Cryptic genetic diversity and complex phylogeography of the boreal North American scorpion, *Paruroctonus boreus*. *Mol Phylogenetics Evol*.
6 – Muhs, D. R. et al. 2003. Eolian sand transport pathways in the southwestern United States: Importance of the Colorado River and local sources. *Quaternary International*, v.104, 3-18.

Study conducted with funding from a USU Undergraduate Research and Creative Opportunity Grant and lab assistance from the USU Department of Biology.